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NRL Report 4741

Copy No. 1

**PROJECT VANGUARD REPORT NO. 4
PROGRESS THROUGH APRIL 15, 1956**

[UNCLASSIFIED TITLE]

Project Vanguard Staff

May 3, 1956

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Previous Project Vanguard Reports

"P.V.R. No. 1, Plans, Procedures, and Progress" by the Project Vanguard Staff, NRL Report 4700 (Secret), January 13, 1956

"P.V.R. No. 2, Report of Progress" by the Project Vanguard Staff, NRL Report 4717 (Confidential), March 7, 1956

"P.V.R. No. 3, Progress Through March 15, 1956" by the Project Vanguard Staff, NRL Report 4728 (Confidential), March 29, 1956

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CONTENTS

Abstract	iii
Problem Status	iv
Authorization	iv
 PREFACE	 1
 COORDINATION WITH OTHER SERVICES	 1
Army	1
Air Force	1
 THE LAUNCHING VEHICLE	 3
Configuration and Design	3
Aerodynamics	3
Propulsion	5
Flight Control	7
Instrumentation and Tracking	11
 THE SATELLITE	 13
Configuration and Design	13
Environmental Studies	15
Instrumentation	15
 THE MINITRACK SYSTEM	 16
Nomenclature	16
Third-Stage Test Vehicle Tracking	17
Initial Prime Minitrack Station on Antigua	17
The Minimum Satellite Minitrack Installation	17
 DATA PROCESSING	 17

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ABSTRACT
[Confidential]

The assembly hangar at AFMTC will be available by 1 April 1957 instead of 1 January; construction of the launching facilities begins by 15 May 1956.

The final criteria for the Antigua Minitrack station have been delivered to BuDocks and the criteria for the Mayaguana and Grand Turk stations have been forwarded to AFMTC. The site-survey party has conferred with IAGS in Panama and has selected sites for a primary and an alternate station in Quito, Ecuador.

The first test vehicle, TV-0, will be launched on 20 November 1956 and not 29 November as erroneously reported.

The launching vehicle weight has been further reduced and preliminary structural vibration data have been obtained. The injector burnout problem in the first-stage powerplant appears to be solved, and work has accelerated on the chamber burnout problem. Studies indicate that improvement in propulsion of the first two stages could result from various fuel and oxidizer modifications. Both third-stage subcontractors are conducting scaled-down test firings.

A design modification is being made in the gyro reference system to overcome excessive deflection in the cast baseplate of the can; an all-transistor flight temperature regulator for this system is being tested, but prelaunch temperature regulation will require cooling means external to the can. Development continues on a magnetic amplifier autopilot as well as on standard and subminiaturized electronic types. A REAC study on the pitch-yaw motor systems indicates that both first and second stages of the vehicle are adequately stabilized.

Two 3-element helix antennas have been delivered and a new contract with NMCA&MA is being negotiated. Contracts have been let for the 25 ppm/am telemetering transmitters, the ppm/am calibrators, and components for the pwm/fm transmitters, and bids are in for the fm/fm transmitters. The ppm/am ground station contractor is behind schedule, and arrangements have been made to borrow one IGY ground station to meet the Vanguard commitment; another is being built at NRL. One pwm/fm ground station has been received and a request is being made to BuAer for the transfer of more pwm/fm components and the loan of an AN/URK-5 fm/fm and pwm/fm ground station. BuAer has granted the use of an AN/FPS-16 (XN-1) radar pending its release by NAMTC Pt. Mugu; AFMTC will supply auxiliary equipment. It is now proposed to locate the XN-1 on Grand Bahama Island and integrate it with the AFMTC mod 3 radar chain.

A BuAer-sponsored conference has resulted in a program for a lightweight range safety command receiver. A range safety beacon now being developed for SCEL appears to be most capable of meeting the Vanguard third-stage environmental conditions; a proposal has been requested. AFMTC has waived, for the mission vehicles, its requirement that all ballistic missiles carry AZUSA transponders for range safety purposes.

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Design continues on several satellite types; only spherical configurations to be separated from the third stage have thus far been considered. Environmental and structural studies are also continuing. A system for internal temperature regulation within the Minitrack requirements is being studied. An experimental ion chamber photon counter for the Lyman-alpha experiment is being fabricated for tests.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem A02-18

Manuscript submitted April 26, 1956

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**PROJECT VANGUARD REPORT NO. 4
PROGRESS THROUGH APRIL 15, 1956
[UNCLASSIFIED TITLE]**

PREFACE

This report is intended as a general summary of the progress on Project Vanguard through 15 April 1956. Hence, minor phases of the work are not discussed to any great extent and technical detail is kept to a minimum. It is hoped that the information here provided will be of value to administrative and liaison personnel in coordinating and planning their activities, and as a guide to the current status of the project. Material of a more technical nature will be published from time to time in separate reports which will be announced in the subsequent monthly progress report.

COORDINATION WITH OTHER SERVICES

Army

Tracking

The South American site-selection survey party departed from the United States on March 26, and initial discussions have been held with IAGS headquarters in Panama. A primary and an alternate site have been selected in Quito, Ecuador, and it is expected that the remaining locations will be selected by the end of April.

Technical Program

At present it is planned to request the Army to develop a program for passive acquisition of the satellite as a supplement to the Minitrack System. Such work was included in early program proposals received from the Signal Corps Engineering Laboratory and the Ballistic Research Laboratories. There is a possibility also that the Ballistic Research Laboratories will develop a method and equipment for a critical portion of second-stage trajectory control (see "Range Instrumentation").

Scientific Program

The Army Map Service (AMS) will be furnished data from electronic tracking of the satellite for geodetic purposes. The data requirements will be extended if the AMS uses the simplified Minitrack (Mark II Minitrack) in its program, since reduction of the data from the latter system requires the extensive use of Prime Minitrack data. The AMS has been referred to the National Academy of Science for further help in its geodetic programs.

Air Force

Test Range Facilities

A series of conferences during the week of 2-6 April clarified test range requirements and support; as a result, a complete test program will be formulated by 25 April.

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The Army Corps of Engineers has declared that the beneficial occupancy date for the Vanguard hangar (Hangar S) is now 1 April 1957 instead of 1 January. This could result in a delay in the test program. The detailed design work on the Vanguard launching facility has been completed and the contract will be awarded by 10 May 1956; construction will begin by 15 May.

The change in the launching date for TV-0 (Viking 13) reported earlier* will be made -- the launching will take place on 20 November 1956 as originally scheduled.

The current planning and construction control dates for the launching facilities are as follows:

Completion of design criteria and topographical survey of site (completed on schedule)	15 February 1956
Final review of detailed design plans (completed 9 March 1956)	15 March 1956
Completion of detailed design; negotiations with selected construction contractors to start (detailed design now completed)	1 May 1956
Actual construction to start	15 May 1956
Joint occupancy of blockhouse and pad by contractor and Vanguard engineers	15 August 1956
Operational occupancy of blockhouse and pad by Vanguard engineers; gantry crane to be operational	15 October 1956
Launching of TV-0 (Viking 13)	20 November 1956
Permanent water installation to be available for use in conducting static firing tests (adequate temporary water supply can be made available by 1 November 1956 or earlier if needed)	1 December 1956
Beneficial occupancy of assembly hangar	1 April 1957

The Antigua site-survey group has completed its mission and the final criteria for this station are being prepared for the Bureau of Yards and Docks. AFMTC has been notified that Minitrack stations will be required on the islands of Mayaguana and Grand Turk, and the criteria for these stations have been forwarded to AFMTC.

* Project Vanguard Report No. 3

THE LAUNCHING VEHICLE

Configuration and Design

Work has continued on the weight optimization program and further reductions in vehicle weight have been achieved; the current empty stage weights are given in Table 1. A simple sketch of the vehicle configuration is shown in Fig. 1.

TABLE 1
Weight Optimization Status and Goals

Stage	Specification Weight (lb)	Target Weight (lb)	Current Weight (lb)
First	1782	1565	1533
Second	973	865	917
Third	89	89	84

A study of overturning moment and structural limitations of the launching vehicle when subjected to wind on the launch stand has been completed. A quick-release clamping system will be provided to restrain the vehicle on the launch stand at the four longeron fittings. The fully loaded vehicle will withstand a 40-knot wind with or without clamps; the empty vehicle will withstand a 60-knot wind with clamps in place.

Preliminary vibration-mode and frequency data on the launching vehicle have been obtained for gyro and control system analysis. The first cantilever frequency (static firing condition) is 1.0 cycle per second. The first free-flight mode frequency is 3.7 cycles per second.

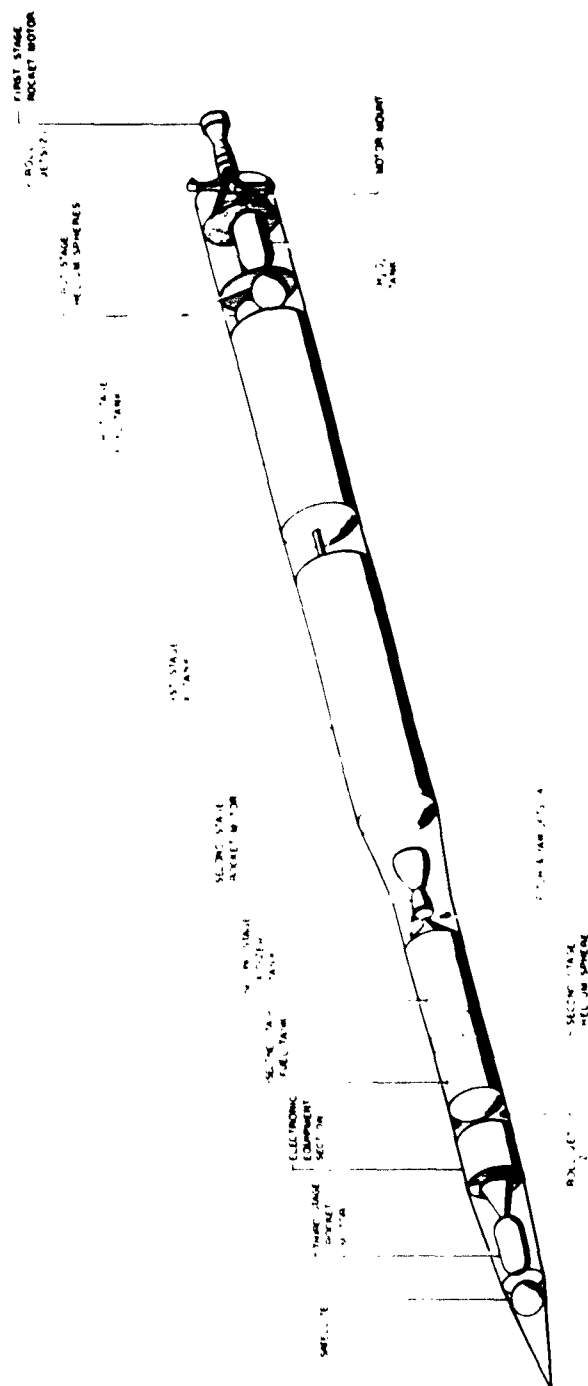
Stress information and drawings have been delivered for manufacture of the following first-stage elements to be destruction tested:

1. Fuel and lox tanks
2. Tail section
3. Structure between tanks
4. Structure forward of lox tank

A program for evaluation and development of Pyrotex 9526D1 (asbestos-phenolic material) has been established to determine the feasibility of using this material in the disposable nose cone.

Aerodynamics

On the basis of refined aerodynamic data, the over-all vehicle aerodynamic loads have been re-evaluated and found to be slightly less than was previously anticipated. Also, aerodynamic smoothness requirements for the external surfaces have been prescribed: no projections from the nose cone are permitted, but the first and second stages may have non-flush rivets, bolts, and welds within specified limitations.



Propulsion

The current values of the chief propulsion parameters are given in Table 2.

TABLE 2

Stage	Nominal Thrust (lb)	Burning Time (sec)	Specific Impulse (sec)	Total Impulse (sec)	Nominal Mixture Ratio O/F	Velocity Contribution (ft/sec)	
						Vert.	Horiz.
First	27,835	141.9	253.5 (Sea Level)	4,170,000	2.2	3,903	4,023
Second	7,750	116.5	278 (Altitude)	900,000	2.8	2,022	8,389
Third	2,350	41.5	245 (Altitude)	97,600	-	-	13,405

First Stage

The fabrication and testing of components for the General Electric Model X-405 rocket engine assembly has continued on schedule.

The thrust-chamber development program has been accelerated, with eight additional static firing tests being conducted on separate chambers in an attempt to solve the problem of chamber burnout. These test chambers were successful in the initial run — some for full duration (120 seconds as dictated by the test facility limitations). However, in every case the chambers failed on subsequent operation. A detailed heat-transfer analysis is being conducted to determine what modifications are necessary to eliminate this difficulty; protective refractory coatings are being investigated, as are fuel-rich spray envelopes.

Static test results indicate that the earlier problem of injector burnout has been solved. Four stainless steel and one aluminum injector are being evaluated, but no final configuration has been determined as yet.

Preliminary testing of the oxidizer, fuel, and hydrogen peroxide valves has been completed and these units are ready for assembly into the first demonstrator engine. The flexible fuel lines and the oxidizer bellows assembly have undergone acceptance tests in which no difficulties were encountered.

Inspection and preliminary tests have been completed on the engine control unit, the starting sequence equipment (ground), and the ignition control unit.

The developmental turbo pumps have undergone eight test runs in which only minor difficulties were encountered. The standard ASME nozzle on the gas generator has proved somewhat more efficient than the nozzle box formerly employed. All steam generator components have successfully withstood repeated operation, and no difficulties with them are anticipated.

The peroxide tank has been enlarged in order to accommodate an increase in the nominal flow rate.

Second Stage

Development of the Aerojet General Model AJ 10-37 propulsion system has continued on schedule. However, no static firing data are available yet.

An aluminum "spaghetti" type thrust chamber has been fabricated by the welding technique. Hydrostatic testing indicated only pinhole leaks, which will be repaired. Two other techniques for bonding the tubes are being considered: fiber-reinforced plastic and brazing. The stainless steel backup unit is being fabricated.

A full-scale nonimpinging showerhead injector has been completed and was scheduled for initial start-chamber testing during the period covered by this report, but a test-system malfunction precluded meeting the schedule. Both stainless steel and aluminum unlike-impinging injectors are being developed.

The gimbal support at the bottom of the oxidizer tank has been strengthened to withstand the expected thrust and control forces with adequate rigidity.

Third Stage

The development and qualification of the solid-propellant propulsion unit for the third stage is being conducted in two parallel programs by the Allegany Ballistics Laboratory (Model 42-DS-4350) and the Grand Central Rocket Company (Model 42-XS-4350). Allegany is presently engaged in small-scale firings to determine interior ballistic data for the selected BDI propellant. The design of a mold for the charge and dome inhibitor is complete. They propose to use a fiberglass-reinforced plastic case as their basic unit, with a heat-treated 4130 steel case as the backup effort. The designs for both cases, and for the sea-level and altitude nozzles are completed and component fabrication is progressing as scheduled.

Grand Central has fired a 15-inch-diameter scaled-down heavy-walled propulsion unit for 10 seconds, and oscillograph traces gave no indication of resonance, excessive regression, or tail-off effects (gradual thrust decay). A second heavy-walled test motor with a full-scale propellant configuration is presently being fabricated. The first lightweight chamber has been designed and fabrication will proceed when the internal ballistics configuration has been substantiated by tests in the heavy-walled chambers.

Performance Improvement Studies

Performance improvement and program backup studies have continued; several developments in this area are listed below.

Lox-Fluorine Oxidizer for First Stage

NRL Memorandum Report 582, "A Method of Improving the Performance of the Vanguard First-Stage Powerplant by Adding Fluorine to the Liquid Oxygen Oxidizer" has been published. Meetings have been held with representatives of the General Electric Company and the NACA Lewis Flight Propulsion Laboratory to discuss a program for determining the feasibility of increasing the performance of the Vanguard vehicle by this means.

Perchloryl-Fluoride Oxidizer for Second Stage

A second NRL Memorandum Report, presently in preparation, reports preliminary studies on the performance increase possible through the use of perchloryl fluoride as the

second-stage oxidizer. The Naval Air Rocket Test Station (NARTS), on a Bureau of Aeronautics problem, is studying the feasibility of using this oxidizer and the performance gain possible thereby.

Propellant Cooling in Second Stage

An investigation of the effects of cooling the propellants prior to loading and during stand-by has been completed. The indicated gain is twofold: (1) the increased propellant density allows a higher stage mass ratio to be achieved, and (2) the capacity of the oxidizer as a coolant is increased.

Diethylenetriamine Fuel for First and Second Stages

Investigations of the use of diethylenetriamine as the fuel for both the first and second stages are being conducted on a separate basis. It is believed that the potential cooling problem in both thrust chambers might be alleviated to some extent by the use of this fuel, and a considerable performance increase for the first stage is indicated.

Flight Control

Two approaches for effecting the flight control program are under consideration: (1) an open-loop trajectory determined solely by vehicle-borne equipment, and (2) a closed-loop trajectory with ground guidance. The following is a brief summary of the tentative flight-path program sequence (Fig. 2) for the first approach.

Ground separation occurs when the first-stage thrust exceeds the gross vehicle weight. At maximum thrust, the approximate relative acceleration is 0.2 g. Attitude stability is effected in pitch and yaw through electrohydraulic controller action upon the gimballed thrust chamber, and in roll through two aft-located swivelling jet nozzles exhausting the hydrogen peroxide decomposition products, from the turbo pump.

The reference system is composed of three single-axis rate-integrating gyros located in the second-stage control compartment. A pitch program is initiated soon after takeoff, and the vehicle is eventually programmed in an approximate zero-normal-force trajectory. First-stage separation occurs at burnout.

The second-stage rocket engine is started during the staging operation. Vehicle control and programming continue as directed by the autopilot, though at reduced external gain owing to the different control-loop characteristics of the second stage. The gimballed second-stage thrust chamber provides pitch and yaw control, while roll stabilization results from the operation of tangentially directed jets of propane gas (is stored in liquid form in a tank located above the fuel tank).

When aerodynamic heading is negligible (20 seconds after first-stage separation) the protective nose cone is jettisoned, exposing the satellite and providing clearance for the second-stage separation. Cutoff of the second-stage engine is given by an integrating accelerometer (measuring along the vehicle's longitudinal axis) when a nominal velocity is attained. A timer is then started to initiate the final staging function (third-stage spin-up, second-stage separation, and third-stage ignition) near the apogee of the ascent path. If this nominal velocity is not attained owing to, for example, premature cutoff, an approximate time-to-apogee is computed for the velocity attained and the timer is reset for the new value.

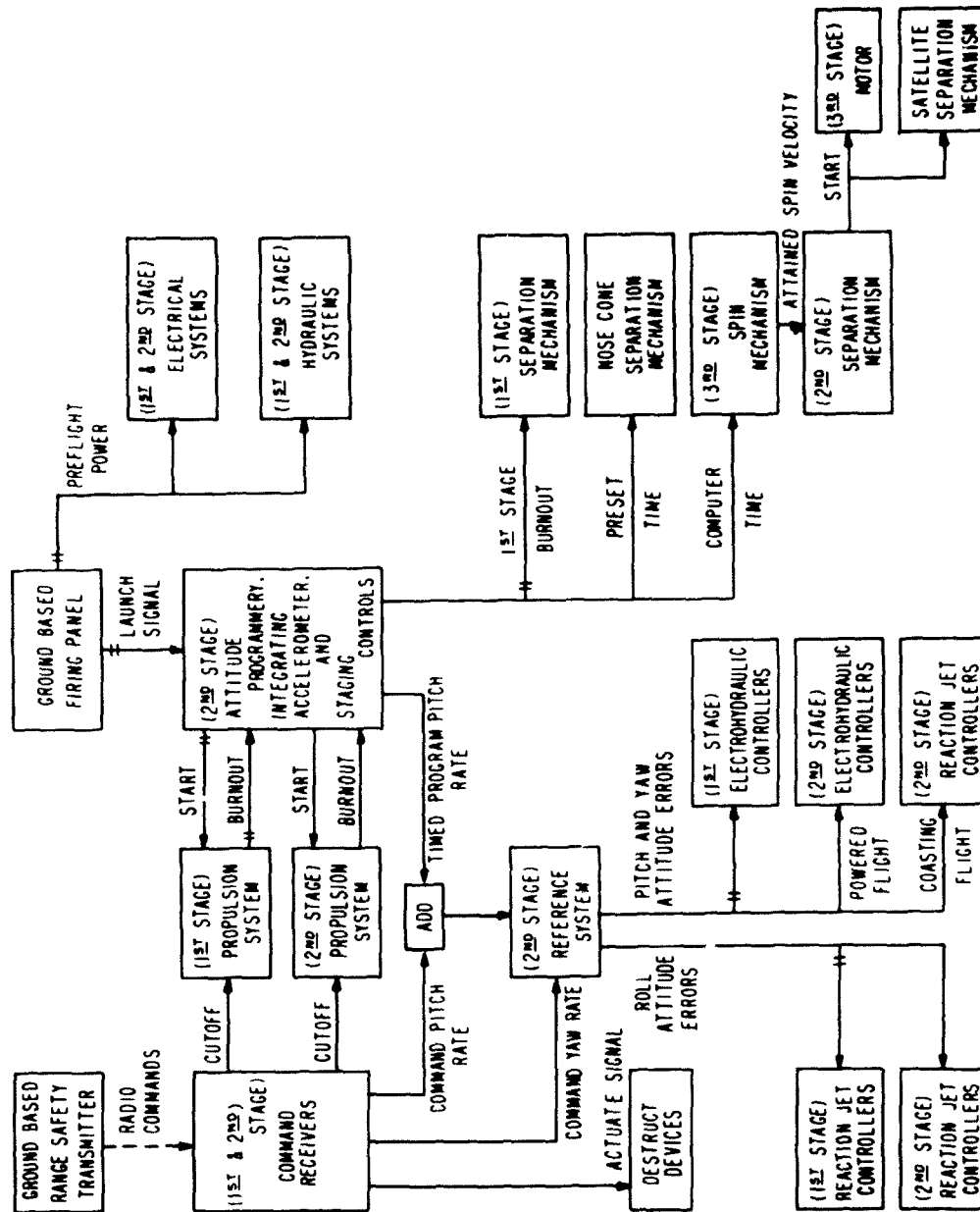


Fig. 2 - Flight path control systems for the Vanguard missile

A controller switchover to reaction systems is effected in all three axes at second-stage cutoff. The pitch program is continued until the vehicle has attained the correct attitude for establishing the third-stage component of the final velocity. At the timer signal the third-stage rocket motor, but not the satellite, is given a spin rate sufficient for gyroscopic stability in powered flight. A differential acceleration between the third and second stages is then provided, followed by ignition of the third-stage rocket motor.

The satellite is accelerated to orbital velocity during the third-stage burning period, at the termination of which the rocket is separated.

Guidance

Reference Systems

A gyro reference system for the Vanguard vehicle is being developed by the Minneapolis-Honeywell Regulator Company. The following are some of the more significant developments in this area.

An experimental investigation has determined the feasibility of using a Deltamax saturation transformer for frequency compensation of the input-torquer current source. Uncompensated gyro torques will be nulled by operating the microsyn position pickoff as a torquer.

It has been found that a cast baseplate for the pressurized gyro can had excessive deflection, and work is progressing on a design modification with top and bottom end bells.

A breadboard model of an all-transistor temperature regulator has been constructed but preliminary tests indicate poor sensitivity. (It was found that the transistors have much lower forward gain than was specified; new transistors have been obtained which meet the specifications.) Prelaunch conditions require external means of cooling the gyro system, and the following possible solutions are being considered:

1. An 80° F air blast and cooling fins on the housing
2. Air at 80° F passed through the can
3. An air blast at 60° F or lower.

Since this gyro system requires close temperature control but not fast warmup from extreme cold, the power input to the gyro heater winding has been reduced.

Prelaunch caging of the gyro is achieved with amplifiers located in the blockhouse; misalignment angles will be corrected by means of this circuit. Testing has been conducted with a cable approximately 300 feet long to substantiate this method.

The servo motor and gear ratio have been selected. An analog computer study of cross-coupling errors in the gyro system indicates that compensation is unwarranted since the effect is less than the uncertainties of gyro drift resulting from vibration and misalignment.

The layout of the test console switching has been established, and a first draft of the test procedure has been written.

Programmer

Requirements for the program timer have been issued for vendor proposals. The function of the programmer is to provide the open-loop pitchover commands for the reference system and to control the several fixed timing sequences associated with staging.

Integrating Accelerometer

The requirement specifications for an integrating accelerometer and timer have been issued to vendors. The function of this device is to determine the vehicle velocity at second-stage burnout and to provide a computed time for third-stage launch.

Attitude Control System

Three types of autopilot are presently under development: a magnetic amplifier type, a subminiaturized electronic type, and a standard electronic type based on the Viking autopilot. Evaluation of the magnetic amplifier type has been completed and Vickers Incorporated has been selected as the vendor.

Transient responses have been computed on the REAC for the first- and second-stage pitch-yaw motor systems. Step inputs of 2 degrees for the first-stage system and 1.5 degrees for the second-stage system were used, and servo limits for δ (the thrust-chamber deflection angle relative to the vehicle longitudinal axis), $\dot{\delta}$, and $\ddot{\delta}$ were placed in the REAC for each run. The results indicate that both stages are adequately stabilized. The amounts of rocket overshoot for a step input at launch, maximum q, first-stage burnout, second-stage ignition, and second-stage burnout were respectively 5, 43, 5, 20, and 0 percent for the nominal values of control system parameters and missile dynamics. The times to reach the maximum value of overshoot for launch, maximum q, first-stage burnout, and second-stage ignition were respectively 1.3, 1.8, 1.2, and 2.4 seconds. The times to reach steady state for launch, maximum q, first-stage burnout, second-stage ignition, and second-stage burnout were respectively 2.9, 10.5, 2.6, 3.4, and 1.0 seconds. Aerodynamic pitching moments at low altitudes were computed for gust conditions and will be included in a stability study.

Staging

A chronologically arranged sequence listing for the flight program has been started on the basis of a requirements statement and detailed breakdown of the individual separation phases. Several schemes are under consideration for structural separation, providing a differential acceleration between stages, and providing power sources for the latter. The following two basic categories of separation have been considered:

1. Immediate separation - This is based on a rapid sequencing of second-stage ignition and structural separation before the first-stage thrust has ceased. The objective is to start the second stage before the vehicle acceleration has become zero or negative, while delaying actual separation until all danger of first-stage "rideup" has passed.
2. Delayed separation - This is based on completing first-stage shutdown, structural separation, and second-stage ignition independently of one another and over a relatively large time interval.

Hydraulic System

The power requirements of the vehicle hydraulic systems have been revised in accordance with the latest control system analysis. The new requirements allow the use of cylinders of minimum size (based upon the natural frequency of the cylinder) in both first- and second-stage systems with pressures of 1425 psi in each. Preliminary specifications for the hydraulic system components of both stages have been prepared on this basis. Preliminary layouts of the actuators and reservoirs for both stages have also been prepared.

Instrumentation and Tracking

Minitrack for Vehicle Tracking

The Minitrack system will be used to track the third stages of the test vehicles; details are given in the section entitled "The Minitrack System."

Telemetering

General

An inquiry is being made to Eastman Kodak concerning the availability of 200-foot rolls of 9.5-inch Verichrome film, which are desired for ground station recording purposes (Eastman has dropped the manufacture of this film in favor of a Verichrome Panchromatic, which is not considered entirely suitable for Vanguard's purpose). Simultaneously a request is being made through the Bureau of Aeronautics for the establishment of an open-end contract with Eastman to furnish film throughout the Vanguard program.

An order has been placed with the Yardney Electric Corporation for silver-cell batteries to handle telemetering and range instrumentation needs for TV's 0-5. Subsequent orders will be placed when the question of whether or not a common power source is to be used in the mission vehicles is resolved.

Four photographic trailers have been obtained free of charge from Army surplus. Two of these will be used as photographic trailers and the other two modified for other purposes. In addition, two trailers to house ppm/am and pwm/fm ground stations have been ordered from Fruehauf.

Two more three-element helix antennas have been delivered by the New Mexico College of Agriculture and Mechanical Arts under the existing contract; a new, ONR-sponsored contract is being negotiated with NMCA&MA to provide antenna development, prototype fabrication, and field service personnel. A contract for four antenna mounts has been initiated with the Houston-Fearless Company.

ppm/am Systems

A contract for 25 ppm/am telemetering transmitters has been let to the James Spivey Company; these are the transmitters to be used alone in the first stages and in addition to the pwm/fm transmitters in the second stages of the test vehicles, and alone in the first stages of the mission vehicles. A prototype unit is expected to be available in August 1956, and the delivery of production models is to begin in November. The contract includes redevelopment of the rf unit to permit easier neutralization. Another contract, for ppm/am telemetering calibrators, has been let to the Lemath Company of Brooklyn, N. Y.

A model of a low-noise insertion amplifier for the ppm/am receivers has been built and tested by the Search Radar Branch of NRL. Indications are that this amplifier, using a GL 6299 tube, has a noise figure of 2.6 to 3.2 db over the telemetering band. It has a bandwidth of 1 Mc and is tunable from the front over a range of 40 Mc. The production of six units has been initiated at the NRL model shop.

The contractor for the ppm/am ground station is still slipping the schedule. In order to meet its commitment, Vanguard has made arrangements to borrow one IGY ground station for early trailer installation. Meanwhile, construction of a ppm/am ground station at NRL, intended for GLM plant checkout use in connection with TV-0, is progressing on schedule.

pwm/fm Systems

A contract for 20 sets of pwm/fm transmitter components has been let to the Applied Science Corporation of Princeton, N. J. (ASCOP). This is the transmitter system to be used alone in the third stages and in addition to the ppm/am transmitters in the second stages of the test vehicles, and alone in the second stages of the mission vehicles. The first delivery of components is expected in the latter part of April 1956.

One pwm/fm ground station has been received from ASCOP six weeks ahead of schedule, and a request has been made to the Bureau of Aeronautics for the transfer of pwm/fm ground station components from Project BULLPUP to Vanguard to enable the Martin Company to run system installation and systems checkout.

fm/fm Systems

Bids have been received for the fm/fm transmitters which will be used in the first or second stages of some of the test vehicles to handle vibration and strain gage data (advantage will be taken of the remaining channels to supplement the ppm/am or pwm/fm systems in monitoring vehicle performance). Procurement has been initiated by NRL for equipment needed for the setup of fm/fm transmitters at the Martin plant.

A request has been made to the Bureau of Aeronautics for the loan of an AN/UKR-5 fm/fm and pwm/fm ground station. This station is intended primarily for laboratory use to aid in the checkout of fm/fm and pwm/fm transmitters.

Range Instrumentation

The Bureau of Aeronautics has officially granted NRL the use of the AN/FPS-16(XN-1) radar now at NAMTC Point Mugu, pending its release by that agency. RCA is still working on a cost proposal for the modification of the XN-1; the modification is to consist of the incorporation of an XN-2 range unit and the provision of digital data pickoffs as well as sine-cosine and synchro outputs for range safety displays; AFMTC has indicated it will provide the plotting-board displays for the sine-cosine data. AFMTC has also agreed to supply ECA digital recorders to permit accurate readout of tracking data. Owing to the long-term time considerations for installation on Grand Bahama Island (GBI) of the AN/FPS-16(XN-2) requested from the Army, it is presently proposed to locate the XN-1 on GBI and integrate it with the AFMTC mod 3 radar chain; the frequency of the XN-1 will be shifted to permit synchronous operation with the mod 3 radars.

RCA has been uniformly requested to investigate the feasibility of using the XN-1 radar data to compute the time of release of the third stage. The Ballistic Research Laboratories are making a proposal for the use of real-time DOVAP information to predict

the time of release of the third stage; this scheme is based on a development of a real-time DOVAP integrator using the existing DOVAP installation at GBL.

The Ballistic Research Laboratories are now manufacturing eight DOVAP transponders in order to assure delivery of equipment prior to commercial production; the commercial contract has not been let. These transponders are to be used in the third stage of TV's 0-4 for vehicle velocity determination. Two additional DOVAP transmitters have been ordered for plant checkout and field use.

Range Safety

At the request of Project Vanguard, the Bureau of Aeronautics held a conference on the general needs for ballistic-missile range safety command receivers. Representatives attended from Vanguard, APL, Douglas, Martin (Baltimore and Denver), Redstone, WADC, NADC, BuAer, and BuOrd special projects. It was the consensus of the conference that the AN/ARW-62 receiver now under development by WADC has the best prospect of meeting the general long-term needs. This receiver, however, uses a discriminator-type decoder and its use would necessitate new coding equipment at AFMTC. Urgent short-term needs of Vanguard, APL, and possibly Redstone would seem to be best met by redeveloping and repackaging the AN/ARW-59 receiver. BuAer is now formulating preliminary specifications taking into account the desires of Vanguard, APL, Douglas, and Redstone. It is the intent of Vanguard to initiate such a contract as soon as possible. It is hoped that support will be forthcoming from these other agencies.

An official request has been made to the Melpar Company for a proposal on suitable S- and C-band beacons. It is apparent that Vanguard's needs in this respect could be met through use of the AN/DPN() now under development for SCEL; this beacon is being developed for use in S, X, and C bands by interchanging the rf heads. The first S- and C-band versions for Vanguard would have to be experimental models; however, this beacon appears more likely to meet the third-stage environmental conditions than any other beacon now in existence. Permission to approach Melpar was granted by SCEL.

Word has reached NRL from AFMTC that all ballistic missile programs will be required to employ AZUSA transponders for range safety purposes; however, a waiver of this regulation for the mission Vanguard vehicles has been obtained by AFMTC. Since the consequences of having to use AZUSA equipment in the test program have not yet been determined, it is not certain whether or not a waiver will be asked for these vehicles.

Trajectory information and equipment plans have been sent to AFMTC in a request for azimuth firing angles; indications are that a release for TV-0 may be granted in the near future.

Range Instrumentation

Partial delivery of S-band test equipment for laboratory, plant, and field checkout of beacons has been made.

THE SATELLITE

Configuration and Design

Design is still proceeding on several types of satellite in the hope of combining the best features of each in the final design, which will be chosen at a future date. The three basic types under current consideration are the following:

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1. The minimum satellite with Minitrack only — This satellite would be the smallest and lightest which could carry the Minitrack transmitter and antennas. The present layouts are based on an unpressurized sphere 6 inches in diameter with four spring-actuated rod-type antennas mounted on the equator; the batteries and electronic equipment would be encased in a cylinder inside two gold-plated radiation heat shields. Both the equipment cylinder and the shields would be supported in the spherical shell by long pins of low thermal conductivity, including four pins attached radially to prevent shifting of the equipment cylinder due to vibration and rotation. The estimated weight of this satellite is less than 4 pounds.

In one variation of the foregoing design, the equipment would be positioned by filling the space between the sphere and the equipment cylinder with a low-density material such as Eccofoam GL (foam-in-place powder). The molding and curing could be done with the electronics and batteries removed. The foam would give excellent support in all directions and should minimize vibrational effects.

2. The minimum satellite with environmental experiments added — Some thought has been given to a minimum satellite as outlined above but modified to include telemetering equipment, erosion and temperature gages on the equator, a temperature gage on the batteries, and a differential pressure gage connected across pressurized zones at the poles. The shell would be a sphere 8 inches in diameter; the estimated total weight is less than 6 pounds.

3. The 20-inch-diameter satellite — Layouts for this type indicate that a pressurized design is feasible. The equipment could be packaged within a pressurized sphere 6 inches in diameter and concentric with the outer shell. Telescoping powder-actuated antennas would be used. The weight would not exceed the 21.5-pound limit.

Any of the foregoing satellite types would be attached to the third stage of the vehicle by a ball thrust bearing which would eliminate high rotational acceleration of the satellite when the third stage is spun. There is no resulting weight penalty, since the bearing is required in any case for mounting the third stage.

All current satellite designs are based on spherical configurations because other configurations make orbital temperature calculations more difficult; however, other configurations will be considered. By the same token, separation from the vehicle third stage is considered necessary for the present designs. Proposals for the separating mechanism, which will weigh about 1 pound, are due from the Diamond Ordnance Fuze Laboratories and the Picatinny Arsenal in April 1956; other contractors will also be requested to submit proposals.

Tensile tests have been run on 0.034-inch sheets of HK31XA-H24 magnesium-thorium alloy to check the published data. This alloy is under current consideration as the material for the satellite skin. In the range from room temperature to 400° F (the highest temperature used in the tests) the yield strength and ultimate strength varied from less to slightly more than the published figures.

A spring-actuated self-locking antenna has been built which may be used on the satellite. This is the lightest of the antennas considered to have excellent reliability but its frail tube construction renders it subject to damage when the vehicle nose cone is jettisoned. The solution presently under consideration is to split the nose cone along its longitudinal axis and jettison the two halves, allowing the antennas to pivot and lock in a plane through the equator of the satellite.

Powder-actuated antennas are to be tested in Aerobee rockets to determine their feasibility for satellite installation.

Environmental Studies

Design of the equipment needed for the satellite environmental simulation tests is progressing on schedule. Procurement is being initiated for a random-motion generating system to be used in simulating the vibration environment of both the satellite package and the launching vehicle electronics.

Measurements of the hemispherical emissivities of spheres at low temperature have been conducted and will continue. A polished aluminum sphere was found to have an emissivity of 0.11 in the range 0° to 103°C , and an Alzak (aluminum coated with 3.9μ of Al_2O_3) sphere had emissivities of 0.73 at -3°C and 0.62 at 101°C . A polished sample of HK31XA-H24 magnesium-thorium alloy was coated with silicon monoxide (SiO) at ERDL, and showed a high emissivity. The problem of visibility and temperature control is a complex one which will require investigation of many possible coatings of widely differing emissivity, absorptivity, and reflectance. The final coating, if any is used, will probably consist of some combination of the coatings being studied.

A design of a system for regulating the temperature of the Minitrack equipment in the minimum satellite has been analyzed. This system utilizes a thermostat-controlled heat exchanger in conjunction with the gold-plated radiation shields. On the basis of the shield characteristics, the mass of the core, and the heat generated inside, it is estimated that the average internal temperature would be higher than is desired; thus increased heat flow to the outer shell would be necessary for a short time when the shell was cooler than the core (i. e., whenever the satellite was on the shaded side of the earth). This change in the heat flow would be accomplished by the thermostatic control. Regulation of temperature by this means should be possible to within $\pm 10^{\circ}\text{C}$ if the shell is spherical, as it is in the present layouts. However, the scheme should be applicable to other configurations as well. A power transfer calculation has been made for a particular configuration of the heat shields and the results were not as favorable as had been hoped, but they did indicate the way an optimum geometry can be approached. Other problems under current consideration include orbital radiation balance for a cylindrical shell, the behavior of insulating materials in vacuo, and a proposal to isolate the payload by using shields of low thermal diffusion.

Instrumentation

The Minitrack system is discussed in a separate section of this report. Developmental work has continued on an ion chamber for measuring Lyman-alpha radiation. The major problem is the high thermal expansion coefficient of lithium fluoride, which precludes the sealing of a window of this material to a rigid structure if it is to experience wide temperature variations. The present technique is to seal the LiF window by means of silver chloride to a thin convoluted silver stamping which is silver-soldered directly to the cylindrical copper cathode of the chamber. This assembly withstands cycling between the temperatures of liquid air and boiling water. Several of these tubes are being manufactured for tests to determine their electrical characteristics and long-term stability of spectral response.

Work is continuing on a magnetic-core peak-current storage circuit to store, for subsequent readout, the peak orbital output of the ion-chamber photon counter in the Lyman-alpha experiment. As a result of a conference with representatives of magnetic material manufacturers, samples have been obtained of magnetic elements which are expected to provide considerably improved and controllable characteristics for this application.

Bids for development and production of the miniature pressure gages for the meteor collision detector are expected by 16 April. The Giannini Company has stated that they can meet the specifications and will submit a bid. Preliminary designs of the amplifier for the meteor collision detector have been completed and a preliminary mechanical design has been fabricated. This will be flown in an Aerobee rocket about 1 May; it is hoped that more definitive orbital data storage requirements of the satellite can be obtained from the results of this experiment.

Preliminary studies have been made of batteries which would be appropriate for powering satellite equipment, and copies of this preliminary information have been presented to the Scientific Systems Committee.

Laboratory breadboard models of three types of telemetry coding systems are now in experimental operation and their characteristics are being studied. Final selection of the satellite system will be made in the near future on the basis of the results of these tests.

A dual-channel tape recorder has been received for experimental use in the study of ground-station data recording and transcription techniques.

Further discussion has been held with component manufacturers regarding mechanical fabrication methods for satellite equipment. The modular wafer type of assembly still seems to offer the greatest weight saving, reliability, flexibility, and structural rigidity.

THE MINITRACK SYSTEM

Nomenclature

The several versions of the Minitrack system have been referred to by various designations in previous reports and publications. As of this writing, the nomenclature of the Minitrack system shall be as follows:

1. The generic term for the radio tracking system of the type initially proposed by NRL for application to satellite acquisition and tracking, without reference to model or specific application, shall be the Minitrack system.
2. The Minitrack system applied to satellite tracking, using a complete antenna arrangement and providing continuous angle determination without ambiguity, shall be called the Prime Minitrack system.
3. The abbreviated Minitrack system, using rf phase-comparison techniques by means of hybrid junctions, which has been variously called the "Poor Man's Minitrack," "Jiffytrack," and "Simplified Minitrack," shall be called the "Mark II Minitrack."

Third-Stage Test Vehicle Tracking

Sites have been selected on the islands of Mayaguana, near AAFB Station 6, and Grand Turk, near AAFB Station 7, for the installation of Minitrack stations to track the third stages of TV's 3, 4, and 5. In addition, these stations will be used during mission operations to track the orbiting phase of the launch. They will not be used to track the satellite. Each station will consist of a complete Minitrack ground electronics unit and seven antennas, each antenna consisting of a single section of the complete antenna array required for the Prime Minitrack stations. Antenna patterns of approximately 45 by 55 degrees will thus be obtained, which will be inclined up to 15 degrees from the zenith in the direction of the expected passage of the vehicles. With this arrangement, coverage of the trajectory is expected for at least 300 miles, even if the launching angle is as low as 107 degrees true. Triangulation is possible for about one third of this distance, to provide actual satellite velocities along the trajectory. AFMTC will assume the responsibility for the establishment and supporting operation of these stations, providing for communications, power, timing, and personnel berthing. NRL will supply the complete Minitrack system, and about three operating personnel during each tracking event. Operational use of these stations is required by 26 April 1957.

Initial Prime Minitrack Station on Antigua

A site has been selected adjacent to Coolidge Airfield north of Parham Harbor on the island of Antigua for the site of the initial Prime Minitrack station. Establishment and supporting operation of this station will be supplied by AFMTC, including communications, power, etc., as required. NRL will supply the complete Minitrack system and up to six operating personnel during each satellite tracking event. Operational use of this station to permit initial testing with TV's 4 and 5 is required by 1 June 1957.

The Minimum Satellite Minitrack Installation

Temperature studies have been made of internal Minitrack packages for the minimum satellite configuration, and indications are that the temperature-regulation requirements for the use of transistors in the package can be met; details are given in the section entitled "Environmental Studies." The total weight of the equipment required is expected to be less than the weight saving made possible by the use of transistors.

DATA PROCESSING

At a meeting on 29 March 1956 at ONR, representatives of NRL and ONR discussed the requirements for the satellite orbit computational facilities with several possible contractors. At the request of one of these companies, the deadline for submission of proposals was delayed a week to 23 April 1956.

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